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DEVELOPMENT OF PHOTOGRAMMETRY IN THE SOVIET UNION

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The significance of photogrammetry is discussed and its development traced in the Soviet Union from pre-Revolutionary times. Development after 1918 is divided into three periods (1918-1929, 1930-1945, 1946-present) and each period is discussed in terms of advances in technology and application, with special attention to those developed within the Soviet Union. Several of these devices are described.

NOTICE

Photogrammetry in our country has advanced from the survey of limited regions of the terrain from surface stations and balloons to the study of the planets and their satellites from automated spacecraft.

The development of domestic photogrammetry is notable for the originality of ideas, methods and instruments and for their wide application to the solution of important problems of the national economy. Photogrammetry developed especially fruitfully after the Great October Socialist Revolution and the creation of the Union of Soviet Socialist Republics. A number of achievements of Soviet scientists in the field of photogrammetry have received general recognition and been recognized by the Lenin and State Prizes, authors certificates and diplomas.

The successful development of photogrammetry and its continuously increasing significance in the solution of various scientific and technical problems has stemmed from the fact that in it are combined the following basic merits :

high precision of measurement, since the images of objects and phenomena on the photographs are obtained with the aid of precision cameras, and the development of the photographs is carried out by rigorous methods with the use of specialized devices and computers;

high productivity, achieved thanks to the fact that instead of studying the objects and phenomena on the ground, the study is carried out of their photographic images in offices;

complete objectivity and authenticity of the results of the investigations, since the images of objects and phenomena are obtained by photographic methods;

the possibility of obtaining information concerning the state of separate parts and of the entire object in a single, extremely short period of time, for example, the deformation of all of the elements of a bridge caused by a load may be instantaneously fixed on photographs and then determined in offices.

the possibility of detailed study of rapidly moving objects and transient phenomena, for example, flying projectiles, volcanic eruptions, deformations of automobile wheels during motion, intensity of motion of urban traffic, etc.

the possibility of studying slow processes, such as soil erosion, the movement of glaciers, settling and deformation of buildings and other structures.

a method of remote study, which has special significance when the object to be studied is inaccessible to direct measurement or when the site of the object presents hazards to human life.

In the second half of the last century Russian scientists and engineers began to employ photogrammetry for earth survey and created original instruments. At that time, earth survey was carried out with terrestrial stations or with stationary balloons.

In 1890-1898, N.O.Viller, B.B.Golitsyn, R.Yu.Tile and P I.Shurov successfully used terrestrial photogrammetry to establish the plans of the separate parts of terrain for the purpose of laying out railways and for other engineering problems.

In Russia, the first aerial photographs from balloons were obtained by A.K.Kovan'ko in 1886 above St.Petersburg.

In order to photograph a larger area from a balloon, P.Yu.Tile in 1898 constructed a "panoramograph" consisting of seven cameras : one central for a plan survey and six lateral for perspective survey of terrain, including the line of the horizon. The panoramograph was supplied by electric surveyor's level which activated the shutters of all of the cameras when the optical axis of the central camera was in a vertical position. The coordinates of the center of the projection of the plan photograph were determined by the geodetic method. The angular elements of the external orientation of the photograph were found according to the line of the horizon. For transformation of the perspective photograph to a plan one, V.F.Naydenov created the rectifier.

S.A.Ul'anin developed an original reconnaissance camera with a sail bogie and a device with a focal length of 100 cm and print size of 24 x 30 cm. In order to determine the elements of the external orientation, in the device were fixed the readings of a barometer and clinometer and, with the help of an additional camera, the horizon was photographed.

In terms of originality and generality of the solution to the problems of terrestrial cartography, the devices of R.Yu.Tile and S.A.Ul'anin surpassed the foreign instruments of that time.

The rapid growth of aerial photography was facilitated by the development of aviation. In order to photograph from an aircraft, the requirements of the aerial cameras were more complex, particularly those of automatization of operation. This problem was successfully resolved by V.M.Potte, who in 1913 created the first semiautomatic aerial camera for plan photographs with a single-disk shutter. With this aerial camera were made numerous aerial photographs during the first World War, mainly for reconnaissance purposes, and also in the post-war period all the way to 1930 for the mapping of the territory of the U.S.S.R.

In the years of the first World War, almost all large-scale operations were carried out with the aid of aerial photographic materials. In the Russian army were created photogrammetry sections and an Aerial Phototopographic Fleet

(' .I.Sreznevskiy, V.M.Potte, ' .F.Naydenov and others).

The first aerial survey from an aircraft with clearly defined measurement goals was carried out in 1914 during the siege of Peremyshl'. On the basis of aerial photographs in March of 1915 a plan of the Mazur Lakes region was prepared with the location of enemy positions. After this, plans from aerial photographs were done systematically in corps and division headquarters.

In order to direct the photogrammetric units of the army, an Aerophotogrammetric Department was set up in Kiev, where an officer's aerophotogrammetric school was located and the journal "Izvestiya po aerofotogrammetrii i tolkovaniyu fotografii" (Review of aerophotogrammetry and photograph interpretation) was published.

The theoretical and practical studies carried out in the field of photogrammetry up to 1917 are reviewed in the fundamental three-volume work of R.Yu. Tile "Fototopografiya v sovremennom razvitii" (Phototopography in contemporary development) (1908, 1909), and also in the book by G.N.Shebuev and N.N.Veselovskiy "Geometricheskie osnovaniya fotogrammetrii" (Geometric foundations of photogrammetry) (1899) and in the monograph by V.F.Naydenov "Izmeritel'naya fotografiya" (Measuring photographs) (1922).

Thus, Russian photogrammetry up to 1917 had a number of achievements and was used chiefly for the solution of military problems. The creation of domestic aerial cameras and photogrammetric instruments was made substantially difficult due to the weak development of optical-mechanical industry in Tzarist Russia.

The reconstruction of the domestic economy in our country after the first World War and the Civil War, and also the industrialization and the collectivization of agriculture, made necessary a speed-up of the mapping of the territory. Within a limited period, this complex problem could be solved only by the method of photogrammetry.

The exceptionally high significance for the development of photogrammetry was due to the decree signed by V.I.Lenin and published March 23, 1919 concerning the establishment of Vysshego geodezicheskogo Upravleniya [now the Glavnoe upravlenie geodezii i kartografii pri Sovete Ministrov SSSR (GUGK)] (Central Administration of Geodesy and Cartography attached to the Soviet of Ministers, USSR). Before this administration was put the problem of territorial mapping with the goal of lending every possible assistance to the development of the productive forces of the country. With the solution of this problem, aerial phototopography and photogrammetry are recognized as the most effective methods of studying the territory for revealing natural resources.

Three periods may be noted in the development of photogrammetry in the Soviet Union.

The first period (1918-1929) is characterized by the organization of photogrammetric undertakings and the training of specialists, and also by the development of a composite technique of aerial photographic survey, and by the first experimental and production work on mapping various regions of the country by this method.

Up to 1924 all aerial surveying work was carried out only by the Military-Topographical Service of the Red Army. In 1918 in the system of the Red Military Air Fleet, the first aerial photographic detachment under the direction of .C.Tsvet-Kolyadinskiy and an aerial survey-photogrammetry school were organized. D.A.Sol'skiy, P.P.Sokolov, . .Naydenov, K. .Chibisov, N.S.Gerasimov and other teachers of this school made large contributions in the training of engineering specialists. A group of graduates of this school later turned to work in the civilian departments and played a decisive role in the formation and development of aerial surveying (N.D.Bogomolov, M.N.Tsiganov, I.N.Istomin and others).

In the aerophototopographic division, maps were put together and corrected according to photographic sketch assembled from separate nontransformed aerial photographs However, the volume of aerial survey and photogrammetric work at that time was small, and plane-table survey remained the basic form of topographic survey in the Military-Topographical Administration during the Civil War and for several years after its end. In spite of this, the advantages of photogrammetric survey were recognized. There were attempts to use a universal method of stereophotogrammetric survey with the aid of the stereoplanigraph. However, this method was not widely developed because of its complexity and the high cost of the device.

In 1924, under the direction of N.M.Aleksapol'skiy, experimental and then production work was carried out on planimetric-composite aerial photosurvey. These works clearly showed that this method has great advantages over plane-table survey, especially when mapping flat and hilly country saturated with contours.

In 1920 photogrammetry began to be taught as an independent discipline in the geodetic faculty of the Mezhevogo Instituta (Land-Survey Institute), in 1921 in the geodetic faculty of Voenno-Inzhenernoy Academii (Military-Engineering Academy), and in 1923 in the Leningradskom Voenno-Topograficheskom Uchilishche (Military-Topographical College). At the same time, scientific investigations were carried out in the field of photogrammetry in the institutes and the academies.

After the end of the Civil War the volunteer societies of the air fleet "Dobrolet" (1924) and "Ukrvozdukhput'" were created. They began carrying out aerial photosurvey and photogrammetric work for the needs of the national economy.

Under the guidance of the "Dobrolet" the State Technical Bureau of Aerial Photosurvey was organized, headed by M.D.Bonch-Bruevich and an aerial photosurvey department was attached to the "Ukrvozdukhput'".

The basic form of work in 1925-1930 was planimetric and planimetric-composite survey. The work was done according to requests from various departments. The Bureau of Aerosurvey, in addition to doing production work, also carried out scientific investigations in order to improve the various processes of planimetric aerial survey. In order to transform aerial photographs, P.P.Sokolov developed an original rectifier and, together with M.M.Aleksapol'skiy, the MGI rectifier.

In the "Ukrvozdukhput'" society an aerial photosurvey venture was organized which prepared photosketches and photomaps in accordance with the order of the administration of the organization of land exploitation and the planning departments of the settlements. In addition, aerial photosurvey enterprise was created in Central Asia, carrying out aerial photosurvey work to satisfy the needs of the Central Asian republics.

Thus, even in the initial period of the development of the Soviet government, aerial photosurvey was widely used, especially in the land- and forest-exploitation. The first works showed great prospects for this progressive method for mapping the territory of our vast country.

During this same time the training of specialists was stepped up. In 1926 at Moskovskom Geodezicheskom Institute (MIIGAiK) (Moscow Geodetic Institute) training in the specialty of photogrammetry was initiated, and in Leningradskom Institute Grazhdanskogo Vozdushnogo Flota (Leningrad

Institute of the Civilian Air Fleet), training in aerial photosurvey. This was the beginning of the planned systematic training of specialists in photogrammetry. Somewhat later, other institutes began the same training : Moskovskiy Institut Zemleustroystva (MIIZ) (Moscow Institute of Land-Exploitation), Novosibirskiy Institut Inzhenerov Geodezii, Aerofotos'emki i Kartografii (NIIGAiK) (Novosibirsk Institute of Geodetic, Aerial Photosurvey and Cartographic Engineers), L'vovskiy Politekhnicheskiy Institut (LPI) (L'vov Polytechnic Institute) and other institutes, and also a number of topographical technical schools.

Scientific work also expanded. In 1929 the Tsentral'-nyy Nauchno-Issledovatel'skiy Institut Geodezii, Aeros'emki i Kartografii (TsNIIGAiK) (Central Scientific Research Institute of Geodetics, Aerial Survey, and Cartography) was formed. Here systematic scientific research began of photogrammetry, directed toward methods of reducing the amount of labor involved in the field work.

In this period and in the following years, scientific work in the field of aerial photosurvey and photogrammetry was also carried out in the departments of Institutes : MIIGAiK, MIIZ, the V.V.Kuybyshev VIA, Moscow State University, LPI and others, and also at the Aerotechniques Laboratory of the AN SSSR (Academy of Sciences, USSR) and in many departmental organizations.

Thus, in the first period, was laid the strong foundation of wide development of Soviet photogrammetry. The composite method of aerial photographic survey, developed at the same time, allowed the increase in the quality of the work and the growth of productivity of the labor, compared with the plane-table survey used at that time as the basic type of topographical survey. For mapping of separate mountain and high-mountain regions, terrestrial stereophotogrammetrical survey was used.

The second period (1930-1945) is distinguished by the use of the composite technique for mapping many regions of the country, and also by the wide application of a differentiated technique of the stereotopographic survey, allowing a significant reduction in field work compared with plane-table suveys and with the composite technique. Aerial phototopological methods have become basic during mapping of the territory of the entire country in a scale of 1 : 100,000 and in separate regions in scales of 1;50,000 and 1:25,000.

The multipurpose method developed abroad at that time for making maps of large scale could not be used in the USSR because of the complexity, costliness, and relatively low productivity of the instruments. Neither could another foreign technique for fine-scale mapping based on the use of perspective photographs obtained by multilens aerial cameras, be used, since it did not allow the required precision of relief image. Therefore, Soviet photogrammetry, resolving the immense problem of creating topographical maps of 1:100,000 scale, followed the path of the development of the new techniques.

In 1930 F.V.Drobyshev organized a laboratory in which original photogrammetric instruments were worked on.

In the beginning of 1930, G.F.Gapochko, F.Ya.Gerasimov and others suggested the VTO technique. It differs from the composite technique in the following way: Contour lines on the photographs are made by stereoscope according to the stake points collected in the field or obtained by simplified methods of photogrammetric concentration of elevation within the limits of each stereogram. From the photographs the contours and the horizontals are placed onto a plot with the aid of a pantograph or an optical transformer.

To reduce further the field work, F.V.Drobyshev, M.D.Konshin, G.V.Romanovskiy, and G.P.Zhukov proposed and worked out in detail an original differentiated method of making maps according to aerial photographs. The technique is based on the use of a stereometer which has correction mechanisms for transformation of differences of longitudinal parallaxes, allowing one to construct horizontals on the plane-table photographs in the presence of only 4-6 altitude points per stereogram. The contours and horizontals were transferred from the photographs onto the plot with the aid of an optical projector. In surveys of flat or hilly regions with a large number of contours, photomaps are made onto which the horizontals are transferred.

At the same time various techniques of photogrammetric condensation of the geodetic base were being created : Phototriangulation, with the use of general purpose stereo-theodolite (A.S.Skiridov), graphical radial phototriangulation (N.M.Aleksapol'skiy, F.V.Drobyshev, G.P.Zhukov, V.A.Deyneko), differentiated method of stereo phototriangulation (G.P. Zhukov), straight line method (G.V.Romanovskiy), technique of undestorted model (M.D.Konshin, G.V.Romanovskiy).

For practical applications of these techniques wide-angle and ultra wide-angle aerial survey lenses (M.M.Rusinov), topographical aerial cameras (S.P.Shokin, G.G.Gordon), stereometers (F.V.Drobyshev), multiplexes (N.V.Viktorov, M.M.Rusinov and others) have been developed and serially manufactured.

In order to increase the precision of the photogrammetric condensation of the skeleton in triangular point, various devices, set-ups and systems have been made and used for determination of the elements of the external orientation of the photographs in flight : altimeter, radar altimeter, gyrostabilization set-ups, the radiogeodetic systems of TsNIIGAiK and "Rym".

The Soviet differentiated method is considerably superior to the American differentiation method of Brock, since the former does not require high-precision rectification of the photographs for the survey of reliefs and contours. F.V.Drobyshev was awarded the State Prize for creation of the stereometer. The works of M.M.Rusinov, M.D.Konshin, G.V.Romanovskiy, N.P.Kozhevnikov, N.P.Viktorov, D.I.Aronov, A.M.Shakhverdov, N.A.Sokolova and L.A.Lukashevich were also recognized by State Prizes in the field of the creation of new aerial survey lenses, ultra wide-angle multiplexes and a method of aerial radar levelling.

The differentiation method has allowed in an extremely limited period mapping on a scale of 1:100,000 of a large territory and creation of high-quality topographical maps which are used in the development of the domestic economy and ensuzing the defense of the country.

During the Great Patriotic War with the aid of aerial photographs enemy fortifications, their battle formations and armaments were showed up, were made and updated the topographical maps and plans of cities, various photodocuments - photographic sketches, photomaps, transformed photographs with reference grids, etc. were created. In the artillery, target and reference coordinents were determined according to aerial photographs by the method of graphical photo-triangulation with the use of scales for laying out initial directions and also according to terrestrial photographs with the aid of a photo range finder (P.A.Mel'nikov, A.N.Lobanov, V.M.Kazakov).

In the second period terrestrial stereophotogrammetric survey also underwent further development in connection with mapping of mountainous and alpine regions. For making maps according to terrestrial photographs, F.V.Drobyshev made a stereoautograph more compact than the corresponding instrument made by Zeiss. The "Aerogeopribor" factory put our a series of Soviet stereoautographs, and the factory "Geodeziya", a series of phototheodolites P.N.Rapasov suggested a method of combination of photogrammetric survey with aerial photosurvey, allowing a reduction of the time neccessary to create maps, compared with the usual terrestrial stereophotogrammetric surveys. This method has been successfully used for mapping the Tien Shan region. As a result of this work, maps have been obtained of inaccessible areas and opened the highest mountain summit - Pobeda Peak (7439.3 m). For this scientific achievement, the scientific Council of the Geographical Society of the USSR awarded a group of topographers, headed by P.N.Rapasov, the P.P.Semenov Gold Medal. The maps of the Tien Shan region are recognized as a remarkable work of Soviet cartography. The authors of these maps, a group of military topographers working under the direction of A.P.Makovkin and A.I.Kozlovskiy, were awarded the State Prize.

During the Great Patriotic War, theoretical studies also continued in the field of photogrammetry, determining the path of its further development. To this period belongs the work of M.G.Kell, N.A.Urmaev and others.

The third period in the development of Soviet photogrammetry (from 1946 to the present) is intimately connected with the post-war reconstruction and development of the national economy. This period is characterized by the further development of the theory of photogrammetry and the development of new methods based on the latest achievements in physics, electronics, mechanics and contemporary computing technology to increase the precision and speed of phototopographic work.

After the completion of mapping the territory of the country on a scale of 1:100,000 and after the transition to surveys scales of 1:25,000 and 1:10,000, there arose the necessity of the development and wide application of new multipurpose stereoinstruments.

The solution to this by no means unimportant problem was favored to a significant degree by the studies of M.D.Konshin, who demonstrated the possibility of stereo-photogrammetric processing of photographs with transformed aiming levels. These investigations were continued by A.N.Lobanov, G.P.Zhukov, and .Ya.Finkovskiy in the monographs "Teoriya transformirovaniya pary snimkov" (The Theory of transformation of photograph pairs), "Vvedenie v teoriyu fotogrammetricheskoy modeli mestnosti" (Introduction to the theory of photogrammetrical terrain models) and "Teoriya kollinearnoy geometricheskoy modeli mestnosti" (Theory of collinear geometric terrain models).

As a result of detailed studies and design work in the USSR for the first time were created stereophotogrammetric instruments of transformed aiming levels - the stereograph of P.V.Drobyshev and the stereoprojector of G.V.Romanovskiy The photographs in these instruments always occupy the horizontal position; because of this, the installation of the observation system is significantly simplified in comparison with the general purpose instruments developed abroad. The effect of the angles of inclination of the photographs in the stereograph and stereoprojector are controlled by correction mechanisms. Here the stereograph is the most compact of all known high-precision general-purpose stereo instruments, since in it the photograph and the model are placed under centers of rotation of three-dimensional levers. The transformation of aiming levels in the stereograph and stereoprojector makes it possible to process photographs with any focal length. The cost of these devices is several times less than the corresponding instruments developed in the capitalist countries.

At the present time, topographical-geodetic enterprises in this country are equipped with SD-3 stereographs and with stereoprojectors. On them are carried out a large amount of work on the creation of topographical maps of various regions according to photographs with focal lengths of 55,70, 100,140, and 200 mm.

For investigation of general-purpose stereodevices, G.A.Oshurkov suggested model photographs, allowing one to estimate the precision of these devices more strictly than by use of control grids.

Simultaneously with the creation of general-purpose stereodevices, methods were being rapidly developed of three-dimensional phototriangulation with transformed aiming levels on stereoplanigraph and multiplex (A.N.Lobanov, G.P.Zhukov, N P.Lavrov and others). These techniques widened the range of application of stereodevices based on the reconstruction of aiming levels existing during photographing of the site. At the present time in photogrammetry a new direction is being developed, namely the creation of orthophotomaps and orthophotomaps with horizontals. For the solution of this problem, E.I.Kalantarov and G.P.Zhukov proposed and developed a slit-rectifier consisting of a triple-projector multiplex and a single projector. After that experimental models were manufactired of the photostereograph of F. .Drobyshev and the stereophotoprojector of G. .Romanovskiy. The experimental work carried out at the TsNIIGAiK on the photostereograph has demonstrated all of the features of slit projection,high precision of this method and the expediency of its development.

Other types of devices for orthophototransformation have been developed at MIIGAiK. Of these let us mention a camera attachment to the SD-3 stereograph and the orthophotoprojector of F.V.Drobyshev - the OFPD. The experimental work carried out on the SD-3 with attachment has shown the good productivity and precision of the method.

In the experimental stage, there is a method of creating orthophotomaps based on tracing of horizontals on a SD-3 stereograph with simultaneous fixation of a profiling program for subsequent orthoprofiling.

In the rectifier of the TsNIIGAiK, the profiling program is written analytically in the form of 3 coordinates of each of a number of points of the model; the profiling itself is done automatically.

In the orthophototransformer OFTD of F. .Drobyshev (MIIGAiK) the program is also created simultaneously with the tracing of the horizontals, but in the form of graphical point profiles The orthoprofiling is done visually by hand according to a point program on the OFTD. Experimental work done under the auspices of the GUGK has shown sufficiently high precision and efficiency and also other merits of this method, demonstrating the necessity of its introduction into production.

In 1970 F.V.Drobyshev was awarded the Lenin Prize for the creation of high-precision general-purpose stereodevices.

With a goal of substantially shortening the geodetic field work connected with aerial photographs and of increasing the precision of photogrammetric condensation of the skeleton in triangulation point, in 1956 A.N.Lobanov proposed, and together with a group of scientific collaborators and production workers, developed an analytical technique of three-dimensional phototriangulation using computors and high-precision measuring device - the stereocomparator.

At the present time this method is the basic and most efficient technique for condensing the skeleton in triangulation point according to aerial photographs

The development and introduction into production of the analytical technique of phototriangulation was to a significant degree made possible by the theoretical work of N.A.Urmaev, especially his monograph "Elementy fotogrammetrii" (Elements of photogrammetry), and the studies in the field of the theory and practice of analytical processing of aerial photographs (I.D.Kargopolov, M.M.Mashimov, F.F.Lysenko, V.A.Polyakova, .Ya.Finkovskiy, F.F.Ovsyannikov, .B.Dubinovskiy, .A.Bulushev, . .Pogorelov, .N.Belykh, I.T.Antipov, G.N.Efimov, and others).

Many production engineers contributed a great deal of work in the detailed development of the technology of this method. Automatic precision stereocomparators were developed (.D.Derviz, E.I.Kolantarov, E. .Filimonov, and others).

The first theoretical and experimental-production works done by the analytical technique of phototriangulation in the ETsVM "Ural-1" and "Strela" are reviewed in the monograph of A.N.Lobanov " ototriangulyatsiya s primeneniem elektronnoy vychislitel'noy mashiny" (Phototriangulation with the aid of computors) (1960).

At the present time two types of analytical routing phototriangulation are in widespread use. The first type is based on the sequential construction of partially dependent models. The elements of the mutual orientation of the photographs are determined according to the results of the measurement of a first stereogram from which systematic errors are eliminated. Then, the elements of external orientation of the first photograph and the first basis of photography are arbitrary selected, and the elements of external orientation of the second photograph, and also the coordinates of the points of the first model, are calculated. A second model is constructed analogously, but as the elements of external orientation of the second photograph the values obtained as a result of the creation of the first model are used instead of arbitrary ones. The second model is brought to scale of the first one according to the aiming levels. Such constructions are carried out up to the end of the scale. As a result, a free network is obtained which is oriented relative to the geodetic system of coordinates according to reference points. In this process, the influence of residual systematic errors is eliminated.

The second type of routing phototriangulation is based on the construction of independent, individual models. In order to do that, only the elements of mutual orientation of the photographs are found; the elements of external orientation are not required. The independent models are joined according to the aiming points in the free network, which is oriented externally as in the first method.

Experimental and production work has demonstrated that with respect to precision and productivity, these methods of routing phototriangulation may be considered equal.

More efficient than routing phototriangulation is block phototriangulation. In the USSR strict versions of block phototriangulation have been developed, based on the simultaneous construction and adjustment of the results of measurement of all photographs of the aerial survey routes, included in the block. The difficulty in the application of these versions is the necessity of solving normal equations of an extremely high order. To overcome this difficulty an iterative method is used with the sequential insertion of unknowns (M.M.Mashimov) and methods of partial exclusion of unknowns (A.F.Lysenko). In addition, a method of quasi-photographs is being investigated, allowing one to generalize the initial information by construction of a general block network (A.N.Lobanov). A quasi-photograph represents a given, for example, central projection of the model of the terrain , created according to a few or many stereograms. By replacing the usual photographs by quasi-photographs, the order of the normal equations may be significantly reduced. A method of equivalent transformation of adjustment equations is also being tested (I.I.Minarevskiy).

In the strict versions of block phototriangulation, a photograph or quasi-photograph serves as the elementary component. In the approximate version, this role is played by an independent model, a group of models or a routing network. In addition, in the approximate versions it is not directly measured values, but their functions which are adjusted.

Of the various versions of block phototriangulation, the approximate ones are mainly used in production. However, the more widespread application of the strict versions, as the more perspective ones, is apparent.

In order to increase the precision of determination of the ground point coordinates, in analytical phototriangulation elements of external orientaion of the photographs are used which are fixed in flight.

Soviet photogrammetry has developed at a rapid pace and in various directions. Aerial survey optics have undergone further improvement, objective methods of estimation of image quality have been created, color photomaterials have been employed which extend the possibilities of office interpretation of aerial photographs, the precision of airborne instruments for determination of the elements of external orientation of the aerial photographs has been increased, many organizations have successfully applied and developed digital methods of photo processing, work is continuing on automatization of stereophotogrammetric measurements which have been started by professor A.S.Skirdov in 1924, electronic phototransformer is being created (M.P.Bordyukov, .I.Smirnov, I.G Zhurkin), there have been proposed and worked out an analytical phototransformer and analytical photocartograph (A.N.Lobanov, I.G.Zhurkin), a device for processing of photographs with random centers of projection (L.N.Vasil'ev), and also an instrument for the planar solution of stereophotogrammetric problems (Ya.I.Gebgard).

The base for photogrammetric instrument construction has been considerably extended in order to develop the new technique and introduce it into production.

Terrestrial stereophotogrammetrical survey is used for making plans of only relatively small areas, when aerial survey is unprofitable. The methods of terrestrial photogrammetry are widely used for the solution of many nontopographical problems, for example, for survey of architectural monuments, for determination of deformations of engineering structures, for determination of the parameters of the eye for preparing contact lenses, etc. Institut Prikladnoy Geodezii (Institute of Applied Geodesy), established not long ago in Novosibirsk, is also involved in the solution of these problems.

For the training of engineering specialists in photogrammetry, a number of text books and training materials have been created and are in wide use (N.M.Aleksapol'skiy, N.A.Blokhin, A.S.Skiridov, F.V.Drobyshev, N.N.Veselovskiy, M.D.Konshin, A.N.Lobanov, N.Ya.Bobir, V.N.Deyneko, G.A.Oshurkov, N.P.Mikhaylov, and others).

New unlimited perspectives have been opened to photogrammetry with the use of spacecraft for study of the earth, moon and other celestial bodies. Soviet science made the first photographs of the back side of the moon and obtained panoramic photographs of the lunar surface. These photographs, and also cosmic photographs of the earth, Venus, and Mars, are used for the solution of various scientific and practical problems.

The achievements of Soviet photogrammetry in the 50 years of the creation of the Soviet Union are the result of the successful development of our socialist government on the path of building a communist society.